

BENTHIC COMMUNITIES AND SEDIMENTARY FACIES IN THE LOWER WITTEBERG GROUP (DEVONIAN, SOUTH AFRICA)

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(With 10 figures)

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ABSTRACT

Rare, Middle–Upper Devonian invertebrate fossils are recorded from a few scattered localities in the lower part of the Witteberg Group. The specimens represent a number of shallow-water communities similar to those recognized in Silurian and Devonian rocks from other parts of the world.

At a single locality near the top of the Weltevrede Formation near Grahamstown, four co-existing communities are recognized: a linguloid–orbiculoid community, a *Tropidoleptus* community, a homalonotid–*Plectonotus* community, and a community of largely infaunal bivalves. Such an assemblage is interpreted as representing the restrictive conditions of an intertidal flat environment.

Analysis of the sedimentary facies shows that the fossils come from a sequence of interbedded shales, siltstones and sandstones arranged in a number of thin upward-fining cycles and displaying flaser, lenticular and wavy bedding. This sequence rests on lithic arenites at the top of an upward-coarsening unit and is overlain by thick cross-bedded quartz arenites of the Witpoort Formation. The top part of the Weltevrede Formation is interpreted as having formed in back-barrier tidal flats during transgressive reworking of a delta top.

In the Western Cape, two localities in the Wagen Drift Formation have yielded a number of brachiopods, including *Tropidoleptus*, *Australospirifer*, chonetaceans and linguloids, as well as bivalves and possible bryozoa. The greater diversity of this brachiopod assemblage suggests somewhat deeper water than the Weltevrede Formation assemblage, probably subtidal. The sedimentary facies of the Wagen Drift Formation are interpreted as having formed in a delta slope environment. The different interpretations of the faunal assemblages from the two areas accord well with the different interpretations of the containing sedimentary facies.

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INTRODUCTION

The Witteberg Group, topmost division of the tripartite Cape Supergroup, is not noted for its invertebrate fossils, although its plant fossils (Plumstead 1967, 1969) and fish fossils (Jubb 1965; Gardiner 1969) are fairly well documented. However, rare marine invertebrates have been recovered from a number of widely spaced localities in the lower part of the group (Fig. 1). Swart (1950) recorded the presence of the inarticulate brachiopod *Lingula* and further indeterminate brachiopods and bivalves in the lowest part of the Witteberg Group in the Wuppertal area. D. K. Toerien (pers. comm. 1978) recalled finding brachiopods and trilobites in Witteberg shales at Howison's Poort, near Grahamstown, some forty years ago. Theron (1962) described moulds of the nautiloid *Orthoceras* and what are possibly bivalve impressions, along with trace fossils, in rocks of the lower Witteberg Group in the Willowmore district. Looek (1967) reported the discovery of a '*Chonetes*' (brachiopod) in sandstones in the lower divisions of the Witteberg Group near Robertson. Hiller & Dunlevey (1978) recorded brachiopods, bivalves and possible bryozoa from one of several localities in the basal unit of the Witteberg Group in the vicinity of Touws River. Theron (1970, 1972), who had also collected in the Touws River area, used brachiopods and a trilobite as a basis for assigning a Lower to Middle Devonian or possibly an Upper Devonian to Lower Carboniferous age to the basal Witteberg beds.

The purpose of the present study was to re-investigate some of the localities, in particular those near Grahamstown in the Eastern Cape and near Touws River in the Western Cape, to see if it was possible to recognize any of the benthic communities that have been described from Silurian and Devonian rocks from other parts of the world, and to see if the environmental information provided by the fossil record was consistent with proposed environmental interpretations

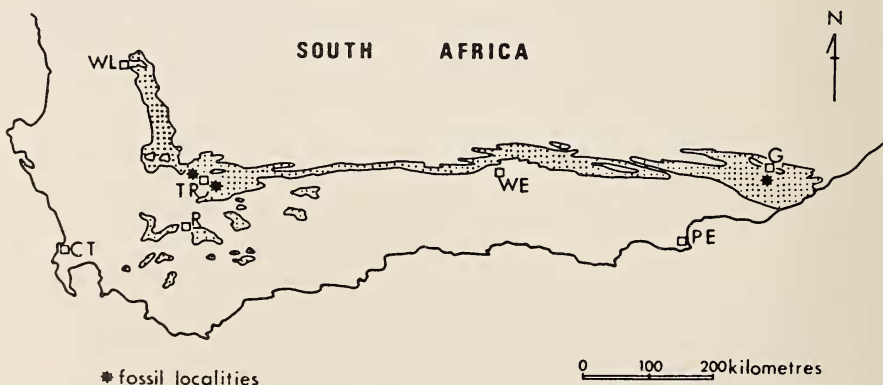


Fig. 1. Map of the major outcrop areas of the Witteberg Group showing the fossil localities. CT—Cape Town, G—Grahamstown, PE—Port Elizabeth, R—Robertson, TR—Touws River, WE—Willowmore, WL—Wuppertal.

based on sedimentary facies analysis. Pickerill & Hurst (1983) have pointed out that the major drawback with many studies that have used fossils to define depth-associated communities, is that they have lacked complimentary facies analysis that could provide corroborative evidence for the environmental assumptions.

STRATIGRAPHY

In the Western Cape, the Wagen Drift Formation is the lowest unit of the Witteberg Group (Fig. 2). It consists essentially of siltstone and shale with interbedded sandstones. Hiller & Dunlevey (1978), working in the Touws River–Montagu area, subdivided that part of the stratigraphy straddling the Bokkeveld Group–Witteberg Group boundary into three formations, of which the upper two were placed in the Witteberg Group. The South African Committee for Stratigraphy (SACS) (1980) regarded these two units as being informal members within their Wagen Drift Formation. The lower, Nougaspoot Member, consists of dirty white, red-weathering, unevenly bedded, quartz arenites separated by thin beds of laminated siltstone. The sandstones show occasional cross-bedding and contain numerous examples of the trace fossil *Zoophycos* (*Spirophyton*). The upper, Byenest Krans Member, comprises micaceous pale grey to white mudstones and thin, medium-grained sandstones, with red siltstone becoming more common towards the top of the unit. In the middle is a thin, cross-bedded, quartz arenite with *Zoophycos* traces. The Byenest Krans Member

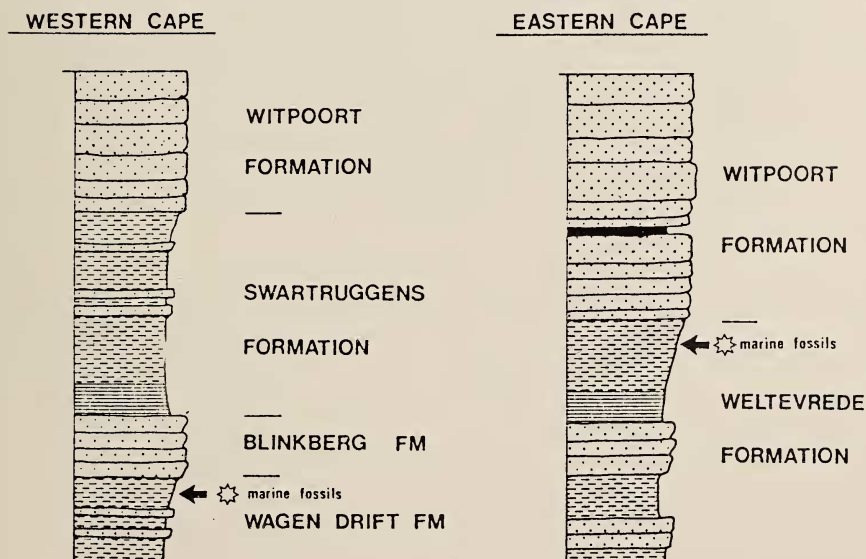


Fig. 2. Stratigraphic columns for the lower part of the Witteberg Group in the Eastern and Western Cape.

has yielded marine invertebrate fossils from three localities in the vicinity of Touws River (Boucot *et al.* 1983).

Overlying the Wagen Drift Formation is the Blinkberg Formation, an extremely mature quartz arenite unit, which contains some plant fossils. This in turn, is overlain by the Swartruggens Formation, a relatively thick heterolithic unit comprising siltstone and shale with thin sandstone interbeds, and containing plant fossils and *Zoophycos* traces. The top of the Weltevrede Subgroup is occupied by the Witpoort Formation, a thick sequence of white-weathering quartz arenites with thin shale partings and containing plant fossils.

In the Eastern Cape the lateral equivalent of the Wagen Drift, Blinkberg and Swartruggens formations is the Weltevrede Formation (Fig. 2). It is a thick succession of shales and siltstones with substantial quartz arenite units, two of which have been accorded member status. At the base of the formation the Driekuilen Sandstone Member occupies much the same position as the Nougaspoot Member does in the west, and near the middle of the formation is the Blinkberg Sandstone Member (SACS 1980). Plant fossils and trace fossils, including burrows, tracks and trails of various kinds, as well as *Zoophycos*, have been found throughout the Weltevrede Formation, whereas the uppermost part has yielded marine invertebrates. Overlying the Weltevrede Formation, the Witpoort Formation again consists of thick cross-bedded quartz arenites and thin carbonaceous shales. Plant fossils and trace fossils have been recorded.

SEDIMENTARY FACIES

In their summary of the depositional environments, Tankard *et al.* (1982) stated that the sedimentation in the lower part of the Witteberg Group was controlled by the continuation of a series of transgressions and regressions that was established earlier in the Bokkeveld times. The lithofacies are relatively sandy and similar to those of the Bokkeveld Group, which have been interpreted as being the deposits of arcuate deltas subject to marine reworking similar to the present-day Brazos River delta of Texas and the São Francisco delta of Brazil (Tankard & Barwis 1982).

Analysis of the sedimentary facies exposed in Howison's Poort, near Grahamstown (Fig. 3), shows that the upper part of the Weltevrede Formation displays two distinct facies associations. A lower upward-coarsening sequence consists of interbedded micaceous shales and siltstones displaying lenticular bedding, passing upward into horizontally laminated and ripple cross-laminated sandstones (Fig. 4). Load structures are a feature of several sandstone-shale contacts. This sequence is interpreted as the product of a prograding distributary mouth bar in a delta complex (Wright 1978). It is overlain by a thin (2 m) upward-fining sequence that shows ripple cross-laminated sandstone with flaser bedding at its base, passing upward gradually into shale. Interpretation of this sequence is made difficult by the fact that it is abruptly truncated by a major erosion surface, but it is thought to be part of an inter-distributary bay fill (Elliot 1974).

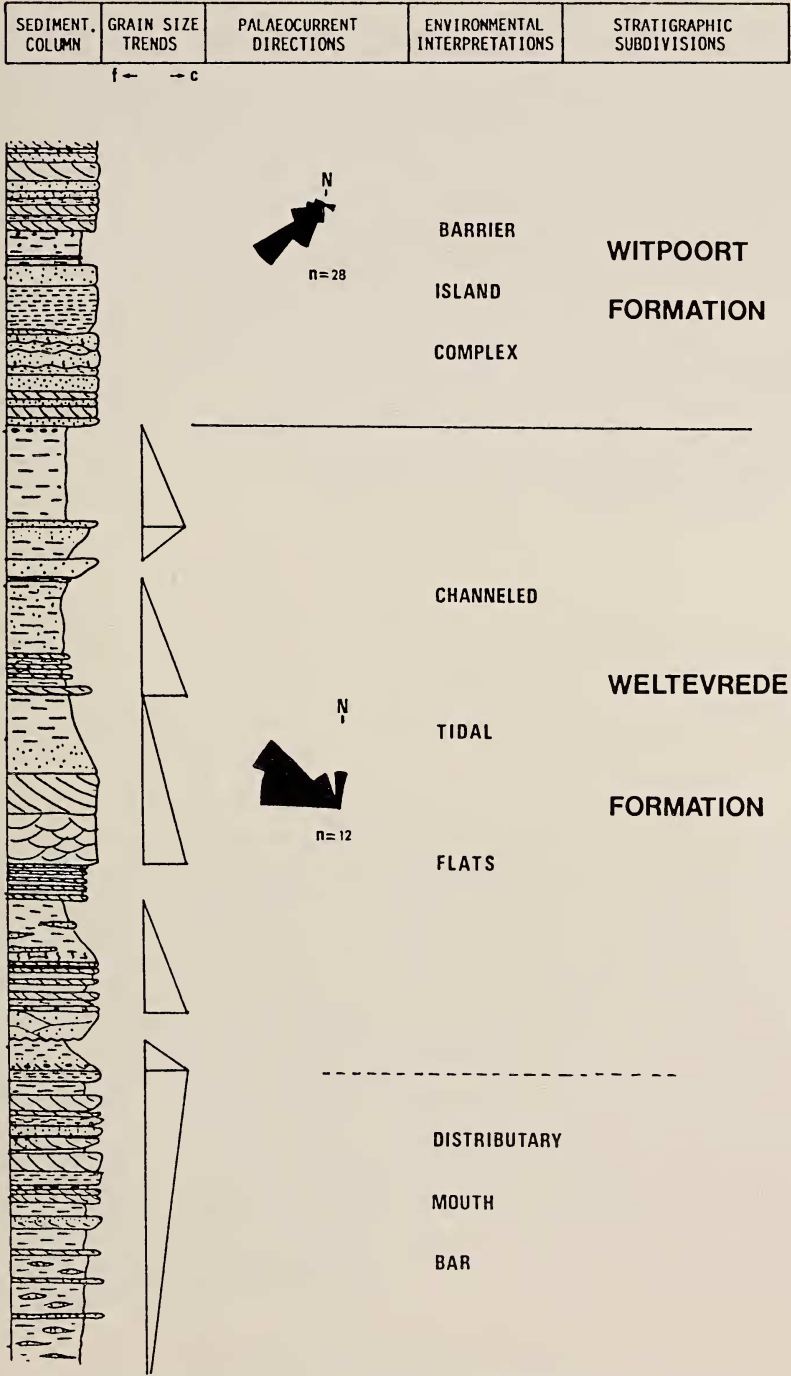


Fig. 3. Stratigraphic log of about 100 m of strata in Howison's Poort, near Grahamstown.



Fig. 4. Top of an upward-coursening sequence in the Weltevrede Formation, Howison's Poort.

The major erosion surface marks the end of the constructional phase of delta out-building and the remaining sediments of the Weltevrede Formation were deposited during a destructional phase. This involved transgressive marine reworking of the delta top (Fisher *et al.* 1969). The upper 70 m of the Weltevrede Formation comprise quartz arenites, siltstones and shales arranged in a number of upward-fining cycles (Fig. 5). The sandstone units thin upwards and are overlain by vertical alternations of siltstone and shale in which flaser and lenticular bedding are common. Trace fossils are common throughout the sequence and marine invertebrates were recovered from the topmost cycle. The upward-fining cycles are interpreted as being the products of a tidal-flat environment crossed by meandering tidal channels (Tankard & Barwis 1982).

The change-over from the Weltevrede Formation to the Witpoort Formation is thought to mark a major change in shoreline configuration from a lobate or arcuate deltaic shoreline to a linear barrier-beach shoreline (Johnson 1976). This change must reflect a reduction in the sediment supply to the shore zone and a decrease in the rate of subsidence so that marginal marine processes rework and redistribute the sediment along the shore. Wave reworking of delta front sands under transgressive conditions produced barrier islands that migrated landwards over the tidal-flat facies.

The Witpoort Formation consists mostly of mature sandstones. In the basal 10–12 m these are brownish in colour, fine to medium grained, and display horizontal lamination and ripple cross-lamination. Above this level the sandstones are cleaner, slightly coarser grained, greyish quartz arenites displaying planar and trough cross-bedding and horizontal lamination. The lowest sand-



Fig. 5. Thin upward-fining sequence near the top of the Weltevrede Formation, Howison's Poort.

stones were probably deposited by wash-over processes into the tidal-flat area. Reinson (1984) has noted that wash-over is one of the main processes by which barrier islands migrate landward and that scouring associated with wash-over is responsible for the initiation of new tidal inlets. The clean quartz arenites that form the bulk of the Witpoort Formation show many of the characteristics of tidal-inlet channel fill, tidal deltas, and beach and foreshore deposits similar to



Fig. 6. Black carbonaceous shale of lagoonal origin, overlain and underlain by barrier island sandstones, Witpoort Formation, Howison's Poort.

those described from various modern environments (e.g. Kumar & Sanders 1974; Hubbard & Barwis 1976; Reddering 1983). The quartz arenite sequence is interrupted by the development of thin (1 m thick) dark grey to black carbonaceous shales with silty layers, siderite nodules and numerous plant fragments. These probably formed in stagnant back-barrier lagoonal or marsh environments (Fig. 6).

A similar detailed facies analysis is not available for the lower part of the Witteberg Group in the Western Cape but Theron (1970) stated that the basal Witteberg beds are part of a regressive cycle that follows directly on from similar cycles in the Bokkeveld Group. Tankard *et al.* (1982) indicated that the Wagen Drift Formation represents the subaqueous portion of a delta and that the overlying quartz arenites of the Blinkberg Formation are the products of reworking of the delta, much the same as Tankard & Barwis (1982) described from the Bokkeveld Group.

FAUNA

The two localities within the Wagen Drift Formation near Touws River, from which material was collected for this study, have yielded an inarticulate brachiopod (Fig. 7E), several articulate brachiopods (Fig. 7D), bivalves and possible bryozoa. Generally, the preservation of the specimens is rather poor and identification beyond generic level is very difficult. The inarticulate brachiopod belongs to the family Lingulidae and specimens in the British Museum (Natural History) have been identified as *Lingula lepta* Clarke, aff. *Trigonoglossa*, and cf. *Barroisella*. The specimens in the author's collection are certainly not *Trigonoglossa*, which has a distinctive ornament, and of the other two identifications *Lingula lepta* seems the more likely. This is a Brazilian species, which is also known from the Bokkeveld Group (Reed 1925). Copper (1977), writing about the Devonian faunas of Brazil, included the species in *Dignomia*, presumably on the basis of its relatively large size and thin shell.

Among the articulate brachiopods *Australospirifer antarctica* (Morris & Sharpe), *Chonetes* sp. and *Tropidoleptus* sp. have been recognized (Boucot *et al.* 1983). The first of these is well known from the Bokkeveld Group and its Falkland Islands and South American correlatives. The bivalves are too poorly preserved for even generic identification.

The assemblage is dominated by brachiopods but their distribution varies within the formation. The articulate brachiopods come from the middle of the unit but recent collecting near the top, just below the junction with the overlying Blinkberg Formation, yielded only specimens of *Lingula lepta*.

The Howison's Poort locality has yielded inarticulate brachiopods, an articulate brachiopod, a homalonotid trilobite, several genera of bivalves, and a bellerophonitid gastropod (Figs 7A–C, 8). The brachiopods include a species of *Lingula*, *Orbiculoidea baini* (Sharpe), which is known from the Bokkeveld Group, the Falkland Islands and Brazil, and the articulate brachiopod

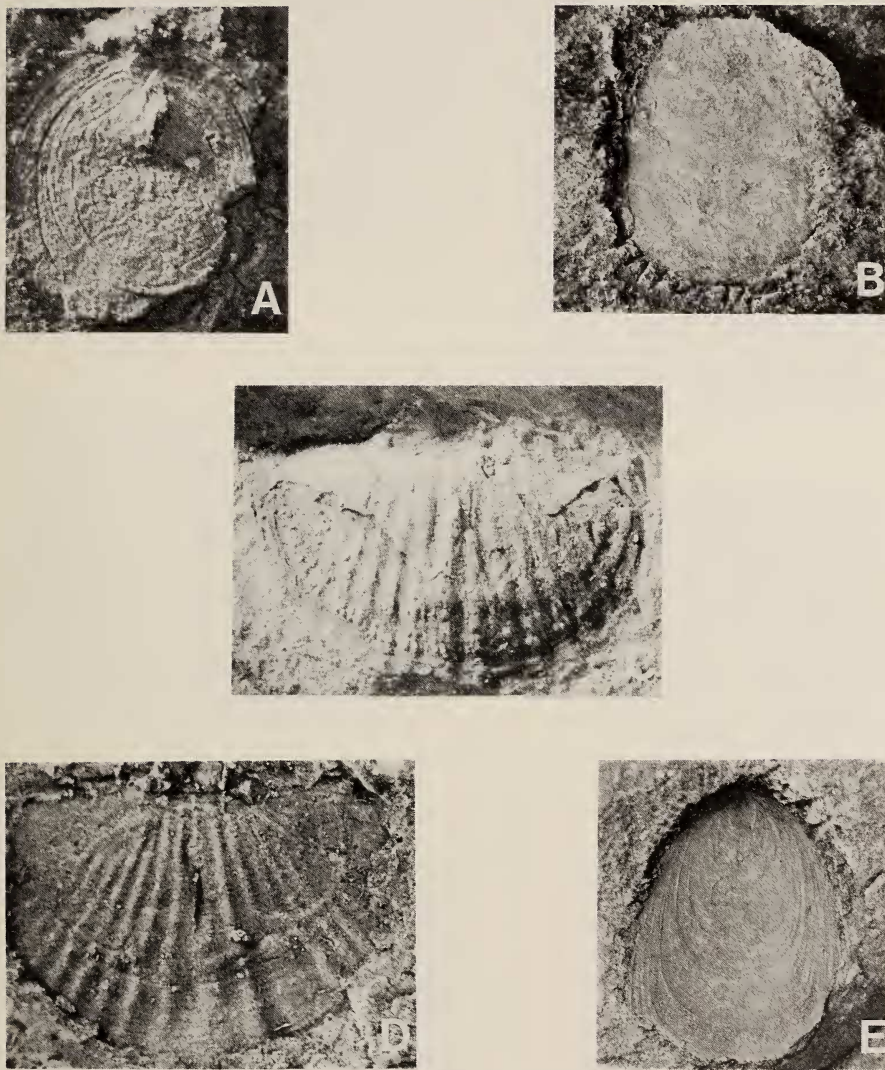


Fig. 7. Brachiopods from the Witteberg Group. A. External mould of a pedicle valve of *Orbiculoidea* sp., Weltevrede Formation, Howison's Poort. $\times 4$. B. External mould of a pedicle valve of *Lingula* sp., Weltevrede Formation, Howison's Poort. $\times 2,5$. C. Internal mould of a brachial valve of *Tropidoleptus* sp., Weltevrede Formation, Howison's Poort. $\times 4$. D. External mould of a brachial valve of *Tropidoleptus* sp., Wagen Drift Formation, Avondrus, south-east of Touws River. $\times 5$. E. External mould of a pedicle valve of *Lingula* sp., Wagen Drift Formation, Elim, west of Touws River. $\times 2,5$.

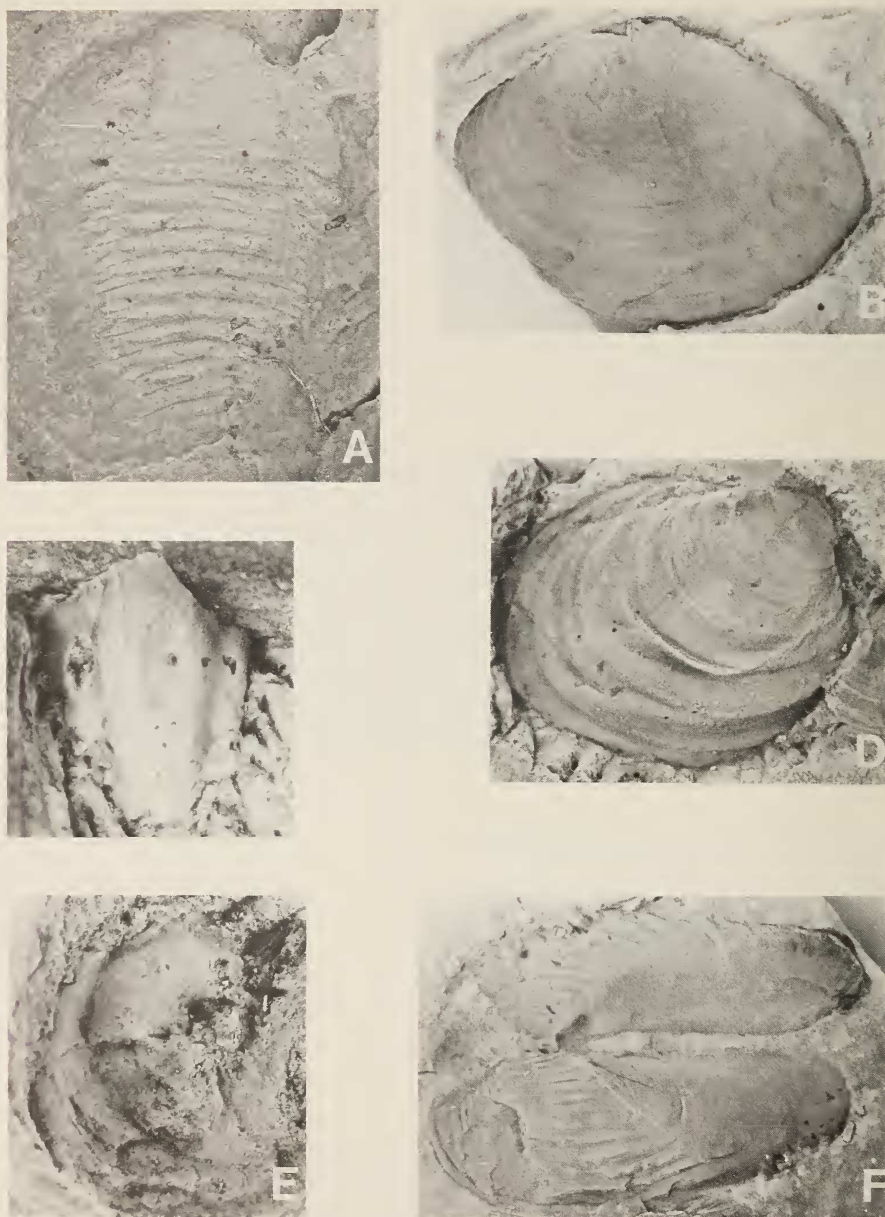


Fig. 8. Fossils from the Weltevrede Formation, Howison's Poort. A. Trilobite, *Trimerus?* sp. $\times 4$. B. Bivalve, *Palaeoneilo* sp. $\times 2$. C. Gastropod, *Plectonotus* sp. $\times 4$. D. Bivalve *Modiomorpha?* sp. $\times 3,5$. E. Gastropod, *Plectonotus* sp. $\times 4$. F. Bivalve, *Sanguinolites* sp. $\times 2,5$. All specimens are preserved as internal moulds.

Tropidoleptus sp. A specimen in the British Museum (Natural History) has been identified as aff. *Trigonoglossa* but again nothing in the author's collection corresponds to such an assignment. The generic placement of the trilobite remains in some doubt but workers at the British Museum (Natural History) believe that it might be a species of *Trimerus* (pers. comm. 1986). Among the bivalves the following genera are tentatively recorded: *Palaeoneilo* sp., *Nuculites* sp., *Sanguinolites* sp., *Paraprothyris* sp., *Janeia* sp., and *Modiomorpha* sp. The collection is thus dominated by bivalves. The single gastropod is a species of *Plectonotus*.

PALAEOECOLOGY

Brachiopods are epifaunal suspension feeders that are restricted to more or less normal marine conditions. The only known exception to this general rule is *Lingula*, which is an infaunal suspension feeder known to be moderately euryhaline and capable of withstanding reduced salinities for short periods. Hammond (1983) showed that a living species of *Lingula* may tolerate salinity levels down to 16‰ and up to 50‰ for prolonged periods, and exposure to levels as low as 5‰ for shorter periods. At the present time the genus lives in nearshore habitats, including estuaries and intertidal flats, often in brackish water, and there is a wealth of evidence to suggest that throughout its stratigraphic range (at least back to the Ordovician), it occurred in nearshore faunas that were characterized by low species diversity usually with no more than five taxa (Raup & Stanley 1971: 208). It seems reasonable to suggest, therefore, that abundant *Lingula* in the Witteberg Group represents a nearshore setting, possibly with fluctuating salinity. However, the greater diversity of brachiopods in the Touws River localities would indicate less stressful salinity conditions. *Orbiculoidea* may have been planktonic or, more likely, epiplanktonic—attaching to algal fronds that are not preserved. Such a life-style would mean that it could turn up in almost any shallow marine habitat but the association of orbiculoid and linguloid brachiopods is a common one in many Silurian and Devonian rocks of nearshore origin (Boucot 1975).

Palaeozoic bivalves were largely non-siphonate and most were shallow infaunal deposit feeders or semi-infaunal suspension feeders (Stanley 1968). In Silurian and Devonian rocks they are commonly associated with *Lingula* in shallow nearshore habitats, although they did range into deeper shelf waters (Copper 1977).

Another common association in Silurian and Devonian rocks is that of homalonotid trilobites with the snail *Plectonotus*, and Boucot (1975) has documented this association from many parts of the world. It is not certain what sort of life habits were adopted by these creatures but the shape of the cephalon on the trilobites suggests they may have foraged for food by ploughing through the upper centimetre or so of sediment. The gastropods may have been herbivores. Homalonotids are known to occur in deeper-water environments, but the

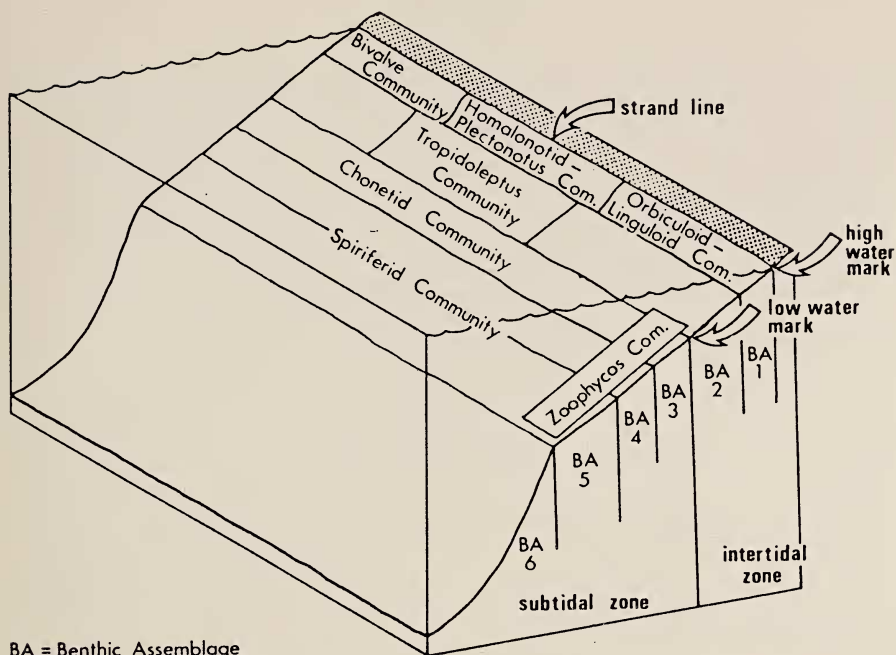
association with *Plectonotus* always seems to occur in a shallow nearshore setting (Boucot 1975).

Associations of this sort just described were termed communities by Boucot (1975), who defined a community as a recurring association of taxa that require the same range of environmental conditions or that are dependent on one another. Using a number of such Palaeozoic communities, based largely on brachiopods, he recognized six benthic assemblages representing increasing distance from the shoreline. This, in turn, could be broadly correlated with increasing depth and decreasing temperature. Each benthic assemblage was made up of one or more co-existing communities.

Benthic assemblages 1 and 2 are interpreted as representing the high and low intertidal zones respectively (Boucot 1975); benthic assemblages 3, 4 and 5 represent increasingly deep subtidal areas on the continental shelf, and benthic assemblage 6 represents deeper water beyond the local shelf edge. For the Malvinokaffric Realm (a Silurian–Devonian palaeogeographic and biogeographic realm that included South Africa, the Falkland Islands and South America south of about 10° S), Boucot (1975: 18) showed that benthic assemblage 1 contains three low-diversity communities—a homalonotid–*Plectonotus* community, an orbiculoid–linguloid community and an infaunal bivalve community. Benthic assemblage 2 contains a number of low-diversity brachiopod communities including a *Tropidoleptus* community. Benthic assemblage 3 contains a high-diversity chonetid community, and a high-diversity spiriferid community stretches across benthic assemblages 4 and 5. The trace fossil *Zoophycos* is said to range through benthic assemblages 3–5. Figure 9 provides a summary of this scheme. A certain amount of community mixing may occur at assemblage boundaries.

The low diversity communities, such as are found in benthic assemblages 1 and 2, can be explained by the restrictive conditions of the intertidal environment with its wide fluctuations in temperature, salinity and exposure to the atmosphere. The more stable infaunal environment permits a somewhat more diverse bivalve fauna to be present. The taxa that dominate the low-diversity communities of benthic assemblages 1 and 2 may also be found in high-diversity communities in deeper-water subtidal conditions (Boucot *et al.* 1983).

The collection of fossils from the Howison's Poort locality clearly relate to benthic assemblages 1 and 2 of Boucot's scheme, and can readily be assigned to the four communities making up those assemblages. This would suggest that the fossils represent an intertidal environment. Figure 10 is a cartoon reconstruction of the environment envisaged for the Howison's Poort site. In contrast, the brachiopod fauna from the Western Cape localities would indicate the deeper-water subtidal conditions of benthic assemblages 3 and 4, although the number of *Lingula* specimens recovered from the top of the Wagen Drift Formation might suggest a progressive shallowing of the environment.



BA = Benthic Assemblage

Fig. 9. Schematic representation of the communities and benthic assemblages recognized in the Witteberg Group, showing their relationship to depth and distance from the shore line. (After Boucot 1975.)

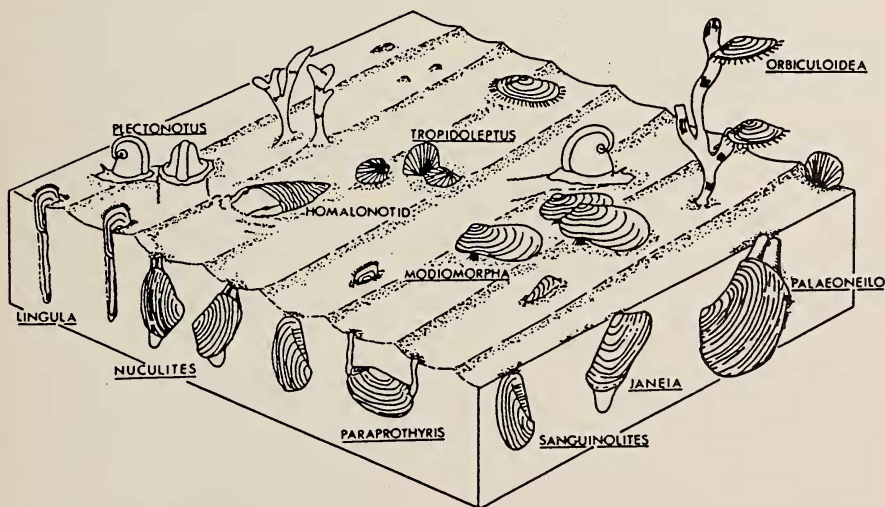


Fig. 10. Cartoon reconstruction of the intertidal communities of the Weltevrede Formation in Howison's Poort.

AGE

The general lack of fossils in the Witteberg Group has made dating of the rocks rather difficult. Fish remains from the Waaipoort Formation in the upper part of the group led Gardiner (1969) to propose a Lower Carboniferous age, whereas Stapleton (1977a, 1977b) used spores from the same horizon to determine a Middle or Upper Devonian (Givetian–Frasnian) age. Witteberg plant macrofossils suggested a late Devonian age to Plumstead (1967, 1969). Boucot *et al.* (1983) discussed these various age determinations and used the presence of the brachiopod *Tropidoleptus*, a genus that apparently does not occur in similar facies in the underlying Bokkeveld Group, to suggest a Givetian or Frasnian age for the lower part of the Witteberg Group.

Such an age determination agrees well with the suggestion of Cooper (1982, 1986), who used eustatic sea-level changes to effect a correlation with Devonian rocks in Europe and North America. His proposals gave a Givetian age for the Wagen Drift Formation and a Frasnian age for the top part of the Weltevrede Formation. This slight age difference is unimportant in explaining the differences in the fauna between the localities described here. As has been pointed out, many of the forms recovered from these localities are quite long ranging and are found in the Bokkeveld Group. Environmental differences are the important factors in determining the faunal differences.

CONCLUSIONS

Rare Middle to Upper Devonian marine invertebrates from a few widespread localities in the lower part of the Witteberg Group represent a number of benthic communities similar to those recorded from other parts of the world. The locality at Howison's Poort in the Eastern Cape has yielded an intertidal assemblage dominated by infaunal bivalves but also containing orbiculoid and linguloid inarticulate brachiopods, *Tropidoleptus* (an articulate brachiopod), a homalonotid trilobite and the gastropod *Plectonotus*. In contrast to this, two localities in the Wagen Drift Formation near Touws River have yielded a deeper-water subtidal assemblage dominated by articulate brachiopods, including *Australospirifer*, *Chonetes* and *Tropidoleptus*. Increasing numbers of the inarticulate *Lingula* near the top of the formation may indicate shallowing of the water.

The different interpretations of the faunal assemblages from the two areas accord well with the different interpretations of the containing sedimentary facies. The shales at the top of the Weltevrede Formation at Howison's Poort are thought to have been deposited in intertidal flats established during transgressive reworking of an abandoned delta lobe. The Wagen Drift Formation is taken to represent a prograding delta and its shales were deposited in a delta slope environment.

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